

ordinary transparent media  $U$  is so small compared with  $u$  that it may be neglected, and puts it zero everywhere.

The results of the various theories differ in the form they give for the dispersion formula. Lommel's theory has been shown by Voigt to be untenable. The theories of Helmholtz, Thomson, and Sellmeier lead, when  $\delta$  is small, to the same result, and give

$$\mu^2 = 1 + \frac{\beta^2 \tau^2}{\rho} \left\{ 1 + \sum \frac{q \tau^2}{\tau^2 - \kappa^2} \right\},$$

which Ketteler's gives

$$\mu^2 = 1 + \frac{\beta^2}{\rho} + \sum \frac{D}{\tau^2 - \kappa^2}.$$

$\tau$  is the period of the ether vibration,  $\kappa$  of the matter vibration, and  $q$ ,  $D$ , &c., are functions of the constants.

Voigt's formula, since he does not consider the matter motion, is different and not so general.

With regard to these formulæ, I am not aware that Helmholtz's has been tested by comparison with experiment. Ketteler's has, and agrees excellently over a long range of values of  $\tau$ .

Double refraction is generally explained by supposing  $\beta^2$  to be a function of the direction; but, as Sir W. Thomson has pointed out, this involves for Helmholtz's theory—he did not, however, apply his formulæ to crystals—dispersion with double refraction. For Ketteler's theory this is not the case.  $\mu$  can be a function of the direction independently of  $\tau$ .

The mechanism which would make the action between the matter and ether in each element of volume a function of the acceleration is perhaps not so easy to conceive as that supposed by Helmholtz and Thomson; but still Ketteler's theory seems to overcome some of the difficulties inherent in the latter.

Either of these theories can be shown to lead to Fresnel's wave-surface, provided we do not consider it necessary that the vibrations should lie in the wave-front. The vibration, as indeed Ketteler and Boussinesq have pointed out, will be normal to the ray. In all other respects Fresnel's construction will hold.

Ketteler and Voigt have tried, without much success, to apply their theories to reflection and refraction.

Thomson, in that most valuable appendix to his Baltimore lectures, has given a complete theory. This can be readily adapted to Ketteler's theory, and the results in many points agree in a striking manner with experiments both for transparent and opaque bodies. The occurrence of a real negative value for  $\mu^2$  is explained by the supposition that the period of the incident light is higher than the highest possible mode of vibration for the matter-molecules in the medium.

The last section deals with Maxwell's electro-magnetic theory of light.

Electro-magnetic disturbance travels in air with a velocity equal to that of light; and in a double refracting medium obeys Fresnel's laws. The difficulty lies in giving a physical explanation of light motions, and of accounting for the mechanical structure of the ether required by the theory. No complete theory of dispersion has yet been given. The work of Willard Gibbs does not explain why there is no dispersion in a vacuum. The objection made to Cauchy's theory holds good. It is probable that some theory such as is developed in the third section may be successfully applied to the electro-magnetic disturbance.

The theory has the great advantage of connecting naturally with the theory of light the important electro and magneto-optical discoveries of Faraday, Kerr, Kundt, and Quincke, and to the development of this much is due to Prof. Fitzgerald. The theory of reflection and refraction as at present developed is only approximate.

### ELECTROLYSIS

PROF. LODGE opened the discussion at the Aberdeen meeting of the British Association on Electrolysis by reading a paper, the notes of which have already appeared in NATURE.

Sir W. Thomson referred, in his remarks on Prof. Lodge's paper, to a matter of importance in electro-plating—viz. the selection which takes place in the electrolysis of solutions containing several salts, as, for instance, in the electrolysis of copper sulphate containing ferrous sulphate, which, when decomposed by a strong current gives a deposit containing impurities, whereas a slower decomposition yields a very pure deposit. Sir W. Thomson spoke also of the necessity for the careful investigation

of those cases in which the formation of deposits between the electrodes had been observed, and it would be important to know whether deposits could be formed in the line of conduction without a nucleus at all. Such matters are of importance to physiology, indicating a possible danger in the passing of long continued currents through the human body.

Prof. Schuster explained the views propounded by Von Helmholtz in his recent papers on this subject. Helmholtz explains the phenomena of electrolysis by assuming a different attraction of different chemical elements for electricity. If this be admitted, most of the difficulties connected with the phenomena of contact electricity disappear. In electrolysis the element (say hydrogen) charged with positive electricity travels to the negative electrode and forms a coating over it. Any electromotive force, however small, is sufficient to produce this effect, as no work is done. The hydrogen does not appear as free hydrogen, however. It is only liberated when the electromotive force is sufficient to produce a transfer of the positive electricity from the hydrogen molecule to the electrode. When the dissociated elements appear in a neutral state an interchange of the electricities of the elements must have occurred before dissociation. In this way we may explain the conversion of stannic in stannous chloride, which was mentioned by Prof. Armstrong in his address. Prof. Schuster did not think that Prof. Lodge had laid sufficient stress on the fact that in very dilute solutions an ion has the same rate of transference, no matter with what element it was combined. This fact affords strong evidence in favour of the above views, from which it follows as a necessary result. Prof. Schuster also explained his own views of the discharge of electricity in gases. He believes that the phenomena present some analogy to those exhibited in electrolysis of liquids. The phenomena exhibited at the negative pole are, he thinks, due to dissociation of the compound molecule. They do not appear in the case of monatomic mercury vapour. Experiments which he hopes to conclude in the next few months will decide whether or not the law of the constancy of molecular charge holds.

The next contribution to the discussion was a paper by Dr. C. R. Alder Wright, containing an account of the nature of his investigations, conducted with the view of measuring Chemical Affinity in terms of E.M.F.

*On the Sensitiveness to Light of Selenium and Sulphur Cells*, by Shelford Bidwell, M.A., LL.B.—The author suggests that the operation of annealing in the making of selenium cells increases the sensitiveness to light by promoting the combination of the selenium with the metal of the electrodes, forming a selenide which completely surrounds the electrodes, and is, perhaps, diffused throughout the selenium when in a liquid condition; further, that the apparently improved conductivity of the selenium, together with the electrolytic phenomena which it exhibits, are to be accounted for by the existence of this selenide. This view finds considerable support in the fact that cells, constructed with sulphur, replacing the selenium and containing a proportion of silver sulphide, are all more or less sensitive to light, and exhibit properties of annealed selenium. The author also read a paper *On the Generation of a Voltaic Current by a Sulphur Cell with a Solid Electrolyte*, a short account of which has already appeared in NATURE (vol. xxxii. p. 345).

### MOLECULAR WEIGHTS

THE discussion on the Molecular Weights of Liquids and solids was opened in Section B of the British Association by the reading of a paper by Prof. A. W. Reinold, F.R.S., the subject of which was the *Size of Molecules*. In this paper an account was given of the different lines of argument by which Sir W. Thomson has been led to form an estimate of the size of molecules. The estimate is based upon four lines of argument—the first, from the refractive dispersion of light; the second, from the phenomena of contact electricity; the third, from liquid films; and the fourth, from the kinetic theory of gases. All four agree in showing that in liquids and transparent solids the mean distance between the centre of contiguous molecules is something between 1/10th and 1/200th of a millionth of a millimetre. Recently Exner (*Monatschrift für Chemie*, vi. 244–278) has proposed another method for estimating the diameter of gaseous molecules, the results obtained by this method being slightly smaller than those deduced from the above. The author gave an account of his experiments on soap-films, conducted conjointly with Prof. Rucker (NATURE, vol. xxxii. p. 210), the results of which are

not out of accord with Sir W. Thomson's estimate of the size of molecules.

*On Macro-molecules, with the Determinations of the Form of some of them*, by Prof. G. Johnstone Stoney, D.Sc., F.R.S.—The author suggested that the molecule of a crystal, which in all probability, consists of several chemical molecules, should be termed a macro-molecule. He then went on to show that it is possible to deduce the form of the macro-molecule from the composition of the chemical molecule; this he illustrated by the cases of iron pyrites, boracite, and quartz.

*An Approximate Determination of the Absolute Amount of the Weight of Chemical Atoms*, by Prof. G. Johnstone Stoney, D.Sc., F.R.S.—The author showed that the mass of a molecule of hydrogen is a quantity of the same order as a decigramme divided by  $10^{24}$ —i.e. a twenty-fourth decigrammet, which is the same as the twenty-fifth grammet. (The grammets are the decimal sub-divisions of the gramme, of which the first is the decigramme, the second the centigramme, &c.) The mass of the chemical atom of hydrogen may be taken to be half the twenty-fifth of the grammet. This value is based on the conclusion arrived at by several physicists—that the number of molecules in a cubic millimetre of a gas at ordinary temperature and pressure is somewhere about a unit eighteen ( $10^{18}$ ), from which it can be shown that the number of molecules per litre must be about a unit twenty-four ( $10^{24}$ ). From this, together with a knowledge of the weight of a litre of hydrogen, the above value for the mass of a molecule of hydrogen has been deduced. The mass of a molecule of hydrogen being known, it is possible now to determine approximately the masses of all other simple substances and of compounds also.

Prof. Osborne Reynolds then made a communication to the Section on the subject of *Dilatancy*, which was also read before Section A (see NATURE, vol. xxxii. p. 535).

*On Physical Molecular Equivalents*, by Prof. F. Guthrie, F.R.S.—The author pointed out that the *cryohydrates* are solid compounds of water and salts possessing very low melting-points, in which the mass ratios, whilst definite, are other than those of the ordinary chemical mass ratios. Another class of somewhat similar compounds has been discovered, which are quite analogous to the ordinary hydrates, and to these the name *sub-cryohydrates* has been given. Metallic alloys are true homologues of the cryohydrates; the ratios in which metals unite to form the alloy possessing the lowest melting-point are never atomic ratios, and when metals do unite in atomic ratios the alloy produced is never *eutectic*, i.e., having a minimum solidifying point. Thus pure cast-iron is not a carbide of iron, but an *eutectic* alloy of carbon and iron. Similar hyperchemical mass ratios are found to exist amongst anhydrous salts; when one salt fused *per se* acts as a solvent to another salt, forming *eutectic* salt alloys, similar to *eutectic* metallic alloys and the cryohydrates. The study of solution affords other instances of masses of unlike matter dealing critically with one another when not in any integral ratio of their molecular masses. Liquids, unsuspected of having chemical or physical relationships, are found, when mixed with one another, either to get warm and finally lose volume, or get cool and gain volume. In the first place chemical union is supposed to take place, and it appears certain that chloroform unites chemically with alcohol, ether with amylene, and benzene with ether, forming bodies analogous to the *sub-cryohydrates* and their prototype the *sub-cryohydrate*  $C_2H_6O + 4H_2O$ . The examination of those cases in which expansion and cooling results from admixture, shows that the maximum effects are produced when the admixture takes place in certain simple molecular weight ratios. This the author proposes to call the maximum molecular repulsion, which, in the case of carbon disulphide and chloroform, is attained with a mixture in which the molecular ratios are  $a : 1 : 1$ . Mixtures in these proportions are found to show abnormally high vapour-tensions. And the author has made experiments which appear to show that, when carbonic acid and hydrogen are mixed, the joint volume is measurably greater than the sum.

*On the Evidence Deducible from the Study of Salts*, by Spencer Umfreville Pickering, M.A.—In this paper the author deals with the evidence as to the molecular weights of salts, derived from a study of the composition (1) of hydrated salts; (2) of basic salts; (3) of double salts. He also criticises the evidence deducible from experiments on hydration, dehydration, and the vapour tension of hydrated salts, and finally examines the conclusions drawn from the calorimetric investigations of such compounds. The conclusions arrived at by the author are

that, although in a few isolated cases the molecular weights obtained would appear to be greater than the analytical results necessitate, still, in a vast majority of cases there are no grounds for multiplying these weights, and indeed there is a considerable mass of evidence in favour of adhering to the simplest possible formulæ. Such a conclusion may, at first sight, appear opposed to conclusions drawn from other sources. On the one hand the author considers it undeniable that if we succeed in determining the number of replaceable portions of the elements in any compound, we determine *ex hypothesi* the number of atoms in the molecule, that is, the molecular weight; and whilst the data at our disposal at present are of the most meagre description, nevertheless are such as seem to point to the simplicity of these molecules. On the other hand, considerations based on the crystalline form and other physical properties of bodies force on us the conclusion that liquid and solid molecules are in all probability of a very complicated nature, certainly more complicated than gaseous molecules. Both these conclusions the author considers to be reconcilable with one another and contends that because the smallest particle of a substance which enters into a chemical reaction may be simple, there can be no reason why many of these particles may not agglomerate and act in unison as regards certain physical forces. That this agglomerate does not act as a unit towards chemical forces would simply imply that the force which unites the individuals constituting it is not chemical force, or is chemical force of such a weak nature that, in presence of the strong chemical agents we make use of, it is inappreciable. The molecule of a chemist is not necessarily identical with the molecule of the physicist.

*On the Molecular Weights of Solids and Salts in Solution*, by Prof. W. A. Tilden, D.Sc., F.R.S.—Accepting the conclusion that bodies in the solid state consist of units or molecules of a very complex character, and made up of a number of such smaller aggregates as compose the molecules of gases, the author is inclined to go further, and sees no reason for limiting the number of small molecules, which may thus be bound together to form a physical unit. From the law of Dulong and Petit, and of Neumann's law, it would appear that in solid elementary bodies, and in salts, &c., there is no difference between molecule and mass, and that the physical unit is the atom. The facts known concerning specific volumes and refraction equivalents support such a conclusion. According to this view solid bodies are composed of atoms, which are only distributed into molecules capable of independent existence; when the body becomes a fluid. Such a view implies that chemical combination between atoms and the combination of molecules which ensues when a gas or liquid returns to the state of a solid are phenomena of the same nature, which agrees with the commonly recognised resemblance between the process of dissociation and those processes of fusion and evaporation. Another consequence of this view is that the idea of limited valency must be confined to gaseous substances. With regard to solutions, many facts are known, which indicate that the molecules of dissolved substances are smaller than those of solids. With regard to the question of water of crystallisation, the author does not altogether agree with the views of Dr. Nicol (see *Report on Solution*, NATURE, vol. xxxii. p. 529), but considers that the composition of the salt molecule in solution is dependent chiefly upon temperature, and in such a way that the dissolved molecule retains the same amount of water as the crystals formed at the same temperature. As the temperature rises these molecules undergo a gradual dissociation, and at a certain temperature the salt molecules lose this water and become anhydrous.

*On the Molecular Constitution of a Solution of Cobaltous Chloride*, by Prof. W. J. Russell, Ph.D., F.R.S.—A thin layer of cobaltous chloride gives an absorption spectrum consisting of two broad, ill-defined bands. If the chloride be mixed with potassium, sodium, or calcium chlorides, the spectrum of these mixtures, both in the solid and fused state, is different from that of cobaltous chloride, and consists essentially of four bands, two of which are marked and characteristic. This same spectrum is obtained with solutions of cobaltous chloride in absolute alcohol, in amyl alcohol, in hydrochloric acid, or in glacial acetic acid. This spectrum would, therefore, appear to be that of cobaltous chloride in an altered molecular state. The spectrum of an aqueous solution is again different, and consists of one broad band nearer to the blue end than the other bands, but the addition of cobaltous chloride to such a solution, or of such bodies as possess an affinity for water, causes a reversion of the spectrum to that of the anhydrous cobaltous chloride. Heat also produces



the same effect, and it would appear from these results that the anhydrous chloride can exist in aqueous solutions. The changes in the character of the spectrum of an aqueous solution produced by heat may be explained as arising from a dissociation of some of the hydrates existing in the solution, and the production of anhydrous cobaltous chloride. Further, the fact that those solutions containing the anhydrous salt more readily transmit the blue rays and absorb the red rays, whilst those containing hydrates in solution more readily transmit the red rays, would indicate that the molecule of the hydrate is smaller than that of the anhydrous salt. The action of water on the anhydrous salt, therefore, is not to form an additive compound, but to split the molecule of the anhydrous salt and form one in which water replaces cobaltous chloride.

In the discussion which followed the reading of these papers Prof. Ramsay said that the density of a saturated vapour afforded a clue to the molecular complicity. Now while a liquid such as water or alcohol gave a saturated vapour, which at a sufficiently low temperature and corresponding low pressure had normal density, the saturated vapour of acetic acid, on the contrary, had an increasing density with fall of temperature, this density showing that the molecule has passed the stage  $C_4H_8O_4$  and is on its way to  $C_6H_{12}O_6$ , if the results are to be explained by agglomeration of simple molecules at all.

Dr. Gladstone remarked that from the evidence of coloured salts in solution such as the sulphocyanides of cobalt, he believed that a dissolved salt might be in an anhydrous condition and might become more and more hydrated as the mass of water in its presence is increased or its temperature lowered. Evidence of other changes might also be obtained from the colour of solutions. He did not think that the refraction of light by a body is often likely to tell anything about its molecular volume; but in the case of the polymeric olefines,  $C_nH_{2n}$ , the specific refraction and dispersion will probably decrease considerably as the value of  $n$  becomes greater, on account of the increasing proportion of carbon in the normal condition.

### UNIVERSITY AND EDUCATIONAL INTELLIGENCE

CAMBRIDGE.—The following have been appointed examiners for the ensuing year:—Physics and Chemistry: Prof. Schuster, F.R.S., and Mr. R. T. Glazebrook, F.R.S.; Chemistry: Messrs. A. Scott and W. J. Sell; Mineralogy: Prof. Liveing; Geology: Messrs. J. J. H. Teall and J. E. Marr; Botany: Messrs. W. Gardiner and H. M. Ward; Human Anatomy: Profs. A. Macalister, F.R.S., and G. D. Thane; Comparative Anatomy: Mr. A. Sedgwick; Physiology: Prof. Michael Foster, Sec.R.S., and Mr. A. S. Lea; Pharmacy and Pharmaceutical Chemistry: Prof. Wyndham Dunstan.

Mr. F. H. Neville, Sidney Sussex College, is appointed as teacher of chemistry with reference to certificates for M.B.

In the late Higher Local Examinations the arithmetic and Euclid were fairly well done.

In Algebra and Trigonometry the cases of gross failure were fewer, while the work of the better candidates was not so good as last year.

Considerable care had been taken to apprehend the facts of Mechanics, but some candidates merely stated a result when asked to "prove" or "establish" it; and when asked to draw inferences by means of the laws of motion, they drew inferences from quite other considerations. A certain amount of knowledge of Descriptive Astronomy was shown by some of the candidates: two of the twenty-two obtained more than half marks.

Only four candidates took the paper in Differential and Integral Calculus. Two of them showed a sound knowledge of the early definitions and rules for differentiation; the other two (who alone attempted the last eight questions) were less successful on the whole, and had confused ideas on the elementary parts of the subject. No marks were obtained in Integral Calculus.

In the Elementary Natural Science paper the work was as a whole extremely poor, notably in Chemistry.

In Physics the candidates seemed to possess very little power of giving concise and definite answers. The attempts to describe experiments and experimental proofs of physical laws were remarkably weak, and might be described as a mere echo of experimental lectures only partially understood; they showed none of the results that might fairly be expected from a careful

consideration of those facts and principles which were clearly within the candidates' reading.

In Physical Geography and Geology most of the papers were good, but none excellent.

In Physiology the answers were on the whole satisfactory, while three or four papers showed that the writers had gained a very creditable acquaintance with the subject.

In Zoology most of the papers were far from creditable, and exhibited but little real or intelligent knowledge. The answers to the practical questions were uniformly bad.

In Botany the candidates displayed but little knowledge of what is meant by the terms "growth," and "collateral," and no one gave a good description of the method of measuring growth. The plant given for description was fairly well described, but the floral diagram was in many cases imperfect. The germination of a seed was not well described. Several students described *Penicillium*, *Mucor*, and *Agaricus*, as parasites.

At Gonville and Caius College an examination will be held on December 8 for open scholarships and exhibitions. Natural Science candidates, who must be under nineteen years of age, will be examined in Physics, Chemistry, Biology, and Animal Physiology; proficiency will be expected in at least two of these subjects, of which chemistry must be one. Further information will be given by the tutors.

At the annual election on November 2 at St. John's College, the following were elected to Fellowships:—A. Harker, M.A., Eighth Wrangler 1882, First Class Nat. Sciences Tripos (Physics) 1883, Woodwardian Demonstrator in Geology; D. W. Samways, M.A. (D.Sc. London), First Class (with distinction in Physics) Nat. Sciences Tripos, 1881, University Extension Lectures in Physics and Physiology; W. H. Bennett, M.A. (M.A. London, Mathematics), First Class Theological Tripos 1882, Tyrwhitt Hebrew Scholar; W. Bateson, B.A., First Class Nat. Sciences Tripos (Zoology) 1883, Assistant Demonstrator of Animal Morphology; R. W. Hogg, B.A., Sixth Wrangler 1883, First Class, Part III., Mathematical Tripos, 1884.

THE annual election of Fellows of St. John's College, Cambridge, took place on Monday, when the five vacancies were filled up by the election of the following graduates of the College:—

(1) A. Harker, M.A., 8th Wrangler, 1882—First-class Natural Sciences Tripos, Part I., June, 1882, First-class Natural Sciences Tripos, Part II., June, 1883, for Physics, Woodwardian Demonstrator in Geology.

(2) D. W. Samways, M.A., D.Sc. London—First-class Natural Sciences Tripos, 1881, distinguished in Physics.

(3) W. H. Bennett, M.A.

(4) W. Bateson, B.A.—First-class Natural Sciences Tripos, Part I., June, 1882, and First-class Natural Sciences Tripos, Part II., June, 1883, for Zoology and Comparative Anatomy, Assistant Demonstrator in Animal Morphology.

(5) R. W. Hogg, B.A., 6th Wrangler, June, 1883, and in the first division Mathematical Tripos, Part III., January, 1884.

PRELIMINARY SCIENTIFIC EXAMINATION OF THE UNIVERSITY OF LONDON.—The following statistics of the Preliminary Scientific Examination for the degree in Medicine of the University of London are of importance as conclusively proving that those members of the medical profession who so urgently declare this examination to be too severe are entirely misinformed. At the examination in last July there passed from all parts of the United Kingdom 159 candidates. Nearly an equal number were rejected; but that this is owing to the fact that the candidates had not sought the usual and proper methods of preparation, and not to the fact that the examination is a specially difficult one, is proved by the following important facts:—63 candidates entered for this examination, stating that they had prepared for the examination wholly or in part at University College, London. Of these 63 candidates 52 passed, and several took honours. Thus less than one-fifth were rejected of those candidates who attended the carefully-organised teaching of University College. This is an exceedingly small proportion of failures for any pass examination. From other London colleges a much smaller number of successful candidates is recorded. The largest number after the University College list is that of St. Bartholomew's Medical School. Instead of 52 we find here, however, 16. Then come Guy's, St. Thomas's, and King's College, each with 11, London Hospital with 5, St. Mary's with 3, and St. George's, Middlesex, and Charing Cross, each with 1. These figures lend strong support to the